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Prairies and Water Management on Corps Lands

by Pamela Bailey

BACKGROUND AND PURPOSE: Approximately 800,000 acres of grasslands have been documented to occur on Corps of Engineers operational projects nationwide (Martin and Peloquin 2005). Results of a recent Corps of Engineers Workshop (U.S. Army Corps of Engineers (USACE) 2006) revealed that many natural resource managers are actively involved in prairie restoration and management (Figure 1), and there is considerable potential to improve prairie communities and associated water resources on project lands throughout the United States. Prairie lands are important for proper watershed-wide management, serving as buffers to adjacent waterways that improve water quality and control water quantity. The conservation and management of these grasslands are critical to terrestrial and aquatic ecosystem quality (The Nature Conservancy 2000). Native prairies function as stable plant communities supporting wildlife, and qualify as meeting the Corps criteria of the "Sustainable Lands Performance Measure," now tracked by the Operations and Maintenance Business Information Link (OMBIL) and incorporated in the Environmental Stewardship Budget Evaluation System (ESBEST). Managing prairie lands offers a sustainable watershed-wide approach that is not only important to Corps reservoirs, but also to waterways nationwide.

Figure 1. Native prairie managed at Tuttle Creek Lake, Kansas (photo courtesy of P. Bailey).

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The purpose of this technical note is to identify and describe how prairie lands affect water quality, quantity, and yield into the receiving bodies of streams, rivers, and lakes. The physical and biological processes are described in the context of the functions prairies provide in maintaining water quality and quantity: 1) filtration, 2) soil formation, 3) nutrient cycling, and 4) controlling water runoff. This note also recommends best management practices (BMPs) including site conversion of fallow land, controlled grazing, control of invasive species, and brush control. BMPs can improve the function of prairies in capturing overland flow of water and reducing runoff, sediment trapping, and control of non-point source pollution. Understanding these natural processes and how prairies function to improve water quality, and balance water yield, will demonstrate why prairie grasslands are critical to the sustainable management of Corps lakes and waterways. This technical note is a product of the Ecosystem Management and Restoration Program (EMRRP) work unit titled "Prairie/Grassland Ecosystems on Corps Projects," as described in Martin and Peloquin (2005).

THE ROLE OF PRAIRIE GRASSES AND FORBS: Vascular plants, particularly grasses, are the most important organisms in the prairie system and provide most of the biomass. Since their weight above ground is exceeded by the amount of roots underground, vascular plants can contribute 2 tons/acre of live organic matter (biomass), and may easily exceed that given climatic conditions (Nagel and Plambeck 1998). Most prairie plants are perennial, storing the carbohydrates produced during the growing season in their roots. The grasses and herbaceous plant community have adapted to capture nutrients efficiently by growing in different seasons (Figure 2). Adaptation of prairie plants that also reduces competition occurs in the C3 and C4 photosynthetic pathways. The cool season C3 grasses are active in the spring and fall, and in shaded areas. The warm season C4 grasses are active in the summer and in full sunlight. Many exotic plant species exhibit the C3 pathway; this enables them to compete and survive with the C4 grasses (Nagel and Plambeck 1998).

Figure 2. Grasses and forbs have evolved together in a Sandhills Prairie owned by the Nature Conservancy in Nebraska (photo courtesy of P. Bailey).

Prairie plant adaptations (Nagel and Plambeck 1998), the important functions these plant adaptations have on water issues, and their overall contribution to the health of the prairie ecosystem are listed below:

- Deep-rooting species provide more area for water and nutrient removal and reduce leaching loss.
- Root structure and the presence of more rhizomes make a more stable sod with less erosion and less encroachment by weedy and exotic species.
- Perennial plants are more efficient at producing biomass, and are more erosion resistant, forming more stable ecosystems.
- Tall plants provide more photosynthetic tissue and are generally more productive, producing more food for consumers and more organic matter for the soil.
- The mix of cool and warm season grasses with C3 and C4 photosynthetic pathways increases productivity, and lengthens the growing season thus regulating nutrients and water resources over a longer period of time.
- Seed constitutes the means of colonizing areas of severe disturbances. Many prairie species have long-lived seed (larger, with a tough seed coat), which promotes continuation of diversity.

Filtration. Grasses and herbaceous plants cover and protect the soil surface from precipitation impacts, reduce soil erosion, increase filtration and improve soil structure and condition. Macroporosity, defined as pores within the soil, is one of the most important factors in determining how water moves into and through soils (Whisenant 1999). Macropores and spaces created by worms, previous root growth, burrowing animals and shrinking clays that cause surficial cracking in the soil surface are routes for water infiltration and air movement in the soil. Macrochannels produced by aggregation of soil particles into distinct structural units, called peds, result in rapid deep wetting of the soil. Macropores drain rapidly but retain a water film absorbed directly into soil particles by weak hydrogen bonds. These small capillary pores are capable of holding water. Soil cover, porosity, aggregate stability, and preferential flow paths all increase the rate of infiltration and decrease runoff. The large particles of organic matter and organic soils have a wide range of pores that can hold twice the water per volume as mineral soils (Naeth et al. 1991).

Any disturbance or management regime that reduces vegetative cover and raises the soil temperature has the potential to reduce soil organic matter and can lead to a cycle of soil degradation (Whisenant 1999). The prolonged loss of vegetative cover results in a crusted soil surface. This crust formation seals the soil surface, reducing infiltration and increasing soil runoff. The reduction of infiltration reduces available water for plant growth, thus decreasing plant growth, which in turn decreases organic inputs to the soil. The soil is exposed to greater temperature extremes by the reduced organic material present in the soil. Fertility of the soil is impacted by the reduction of organic material, which reduces the biotic activity of microorganisms and macroorganisms (e.g., worms). This decreased activity deteriorates the soil structure, further decreasing nutrient and water-holding capacity of the soil. Disturbances such as plowing, intensive row cropping, overgrazing, and erosion reduce organic matter and create major impacts on soil health. Cultivation significantly reduces the amount and size distribution of water-stable aggregates. Cultivated soils may need 30-50 years for the redistribution of water-stable aggregates to approach that of uncultivated soils (Tisdale and Oades 1982). In Illinois, Jastrow (1987) found recovery of the larger water-stable aggregates

(>0.01 in. and <0.75 in.) after cultivation to be more closely associated with prairie grasses than any other vegetation. By maintaining and increasing infiltration, autogenic mechanisms can lead to the recovery of essential soil processes.

The Role of Organic Matter in Soil Formation. In a prairie system the underground growth of plant roots and biomass is a distinct feature of the prairie biome. Prairie systems have relatively deep penetration of roots, and some grasses and forbs have root systems that penetrate the soil to depths from 10–20 ft (Nagel and Plambeck 1998). Prairie native grasses and herbaceous plants have evolved together, creating stratified root systems with various plant species growing to different depths, to compete for nutrients and water at different depths within the soil. These roots have an abundance of root hairs, enabling prairie plants to absorb the sparse soil moisture and maintain the soil nutrients present (Nagel and Plambeck 1998). The prairie ecosystems build up a thick layer of nutrient-rich sod that has an abundance of organic matter. There is also an inverse relationship between root biomass and mean annual temperature; the warmer the temperature, the less root biomass. In desert grassland there is less root biomass than in other types of grassland. Shortgrass prairie, mixed grass prairie, and mountain grasslands have the largest peaks in root biomass of all grassland types (Sims and Singh 1978).

Grasslands have relatively uniform distribution of resources such as water, nitrogen, and organic matter. Where vegetation and organic materials cover the soil surface and roots occur at depths 18 in. or greater in the soil profile, biotic mechanisms will regulate water and nutrient flows. Organic matter is an important biotic regulator of resource flows. In healthy grasslands, biologically driven mechanisms regulate resource flows on a very fine scale, with terrain having less influence (Whisenant 1999).

The soil organic matter content reaches equilibrium between humus formation (favored by high inputs of residues) and humus loss (favored by moist soil and high temperatures). Waterlogged soils with anaerobic conditions have a slow decomposition rate that allows for greater accumulations of organic matter, whereas elevated soil temperature leads to rapid decomposition of soil organic matter. Thus, in a hot, wet environment, soils tend to have low humus content, while in a cold environment soils have higher humus content. This equilibrium remains constant until disturbance occurs or management actions alter the condition. The maintenance of stable soil with organic aggregate is essential to the proper management of soils. Repair strategies that increase the aggregate stability of the soil play a major role in returning proper functions to the ecosystem (Packard and Mutel 1997).

Nutrient Cycling. Microbiotic and macrobiotic organisms co-existing in a symbiotic community are important to nutrient cycling within a prairie ecosystem. Functions they perform include the uptake of nutrients and water, conversion of one chemical form to another, buffering of pH, and releasing nutrients by the decomposition and mineralization of the soil's organic matter. They also improve the porosity of the soil for both water and air, reduce water leaching out of the soil, fix nitrogen from the atmosphere for the soil, transform minerals to soils, and maintain energy and nutrient flow throughout the system by keeping the soil mixed vertically (Nagel and Plambeck 1998). These organisms include algae, actinomycetes, lichens, and liverworts, which fix nitrogen to a usable form for plant uptake in the nitrogen cycle, break down the detritis in the carbon cycle, and improve soil stability. Microfauna include protozoa, nematodes, rotifers, and tardigrades. Nematodes

are diverse plant and animal parasites, predators, and decomposers. Animal mesofauna important to nutrient cycling are mites and springtails, which feed on organic material and shred large particles to provide more surface area for the microbes to carry out decomposition. Important macrofauna include earthworms, insects, ants, centipedes, and millipedes. Not only do worms break down organic matter, they open up the soil and improve its structure vertically within the soil. Harvester ants continually mix the soil in building their mounds, making a significant contribution in the prairie lands where they occur (Nagel and Plambeck 1998).

The carbon cycle. The source of all fixed carbon both in living organisms and fossil deposits is carbon dioxide (CO2), found in the atmosphere and dissolved in the waters of the earth (Figure 3). Carbon is the major element involved in the fixation of energy by photosynthesis and therefore, is closely tied to energy flow. Photosynthesis converts carbon, oxygen, and hydrogen in the presence of sunlight, to a simple carbohydrate, glucose. During both day and night, plants continually carry out respiration, with glucose being oxidized to yield carbon dioxide, water, and energy. From 180 g of glucose, a plant produces 162 g of cellulose and 18 g of water. Each kilogram of cellulose produced then removes 1.6 kg of carbon dioxide from the atmosphere (Smith 1974).

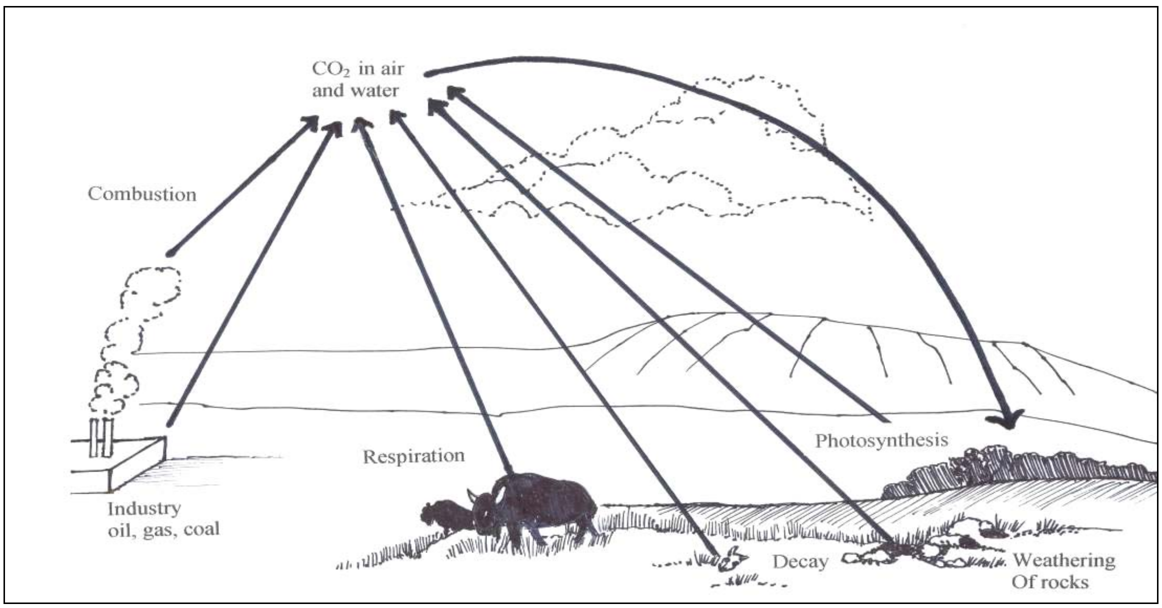

Figure 3. The carbon cycle in a prairie system (adapted from Smith (1974)).

In the terrestrial environment carbon contained in animal wastes and protoplasm of plants and animals is released eventually by assorted decomposer organisms. Bacteria and actinomycetes play a major role in recycling carbon and many other substances. Rate of release varies with environmental conditions such as soil moisture, temperature, and precipitation. In the tropics carbon is quickly recycled and there is little accumulation in the soil, whereas in drier regions, such as grasslands, considerable quantities of carbon are stored as humus. In swamps and marshes, where dead material falls into the water, organic carbon is not completely mineralized and is stored as raw peat or humus and circulated slowly (Smith 1974).

The nitrogen cycle. Most of the nitrogen obtained by plants is derived from the soil in the form of inorganic compounds taken in by their roots. These compounds contain nitrogen that is chemically combined with oxygen or hydrogen, which is produced by bacteria or fungi as they break down complex molecules of organic matter (Stern 1985). Bacteria, actinomycetes and fungi are also responsible in changing nitrogen from nitrite (NO2) to nitrate (NO3), so the nitrogen is readily available for plant use and can be taken up by root hairs (Figure 4). Mycorrhizae, a particular type of root hair, is the combination of a fungus and tissues of the host vascular plant, which grow together. This mutualistic relationship provides more root area for the plant to increase nutrient and water uptake (and the fungus benefits by obtaining photosynthetic products that are otherwise inaccessible). Also within the nitrogen cycle, nitrogen (N) is consumed by denitrifying bacteria which convert nitrate (NO3) to inert dinitrogen gas (N2) (Korum 1992).

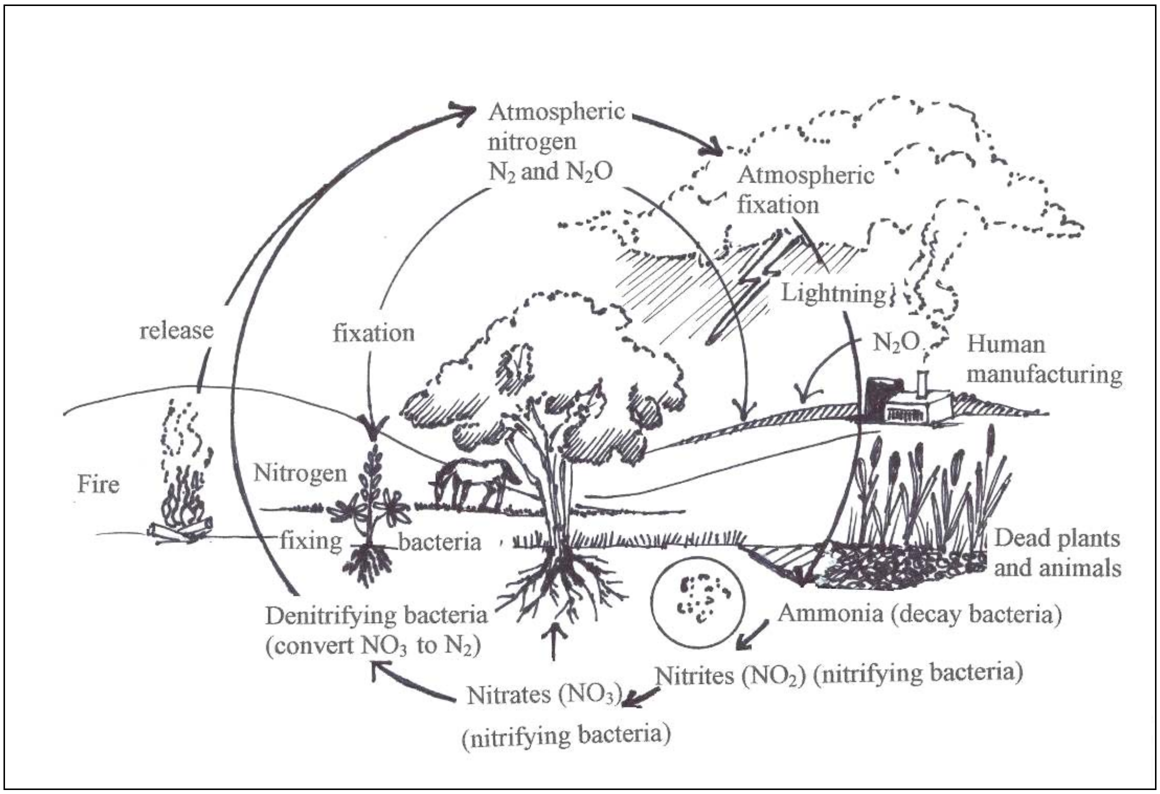

Figure 4. The Nitrogen Cycle (adapted from Smith (1974)).

Some of the nitrogen in the atmosphere is also fixed, or converted to ammonia by various nitrogen-fixing bacteria. Within another part of the nitrogen cycle these microorganisms form a mutualistic relationship with perennial nitrogen-fixing legumes (Fabaceae family) allowing the plant to take nitrogen directly from the atmosphere. Legumes are an essential component in the prairie ecosystem because they provide almost all the new nitrogen fertilizer added to the ecosystem (Nagel and Plambeck 1998). This symbiotic nitrogen fixation process occurs in nodules that are attached to the roots of the legume. Within the nodule, the breakdown of N2 (a stable chemical compound unavailable to plants) occurs to produce nitrogen (N), which the plant can take up. Many plant species that are pioneers in succession also have this ability. Nutrient demand and plant response change with age and successional status, thus ecosystems conserve more nutrients as they mature

(Odum 1969). Mid-to late seral stages are adapted to low nitrogen availability, whereas the early seral stages are adapted to more nitrogen availability (Whisenant 1999). The form of each nutrient/mineral resource is critical. The form of nitrogen changes during prairie development with nitrate-nitrogen (NO3-N) dominating in early prairie development (Stern 1985). Mature prairies produce more biomass per unit nitrogen with ammonium nitrate (NH4-N) than with NO3-N (Pickett et al. 1987) and the soil microorganisms recycle nitrogen in the prairie system so that little is lost via leaching.

Controlling Water Runoff. Proper restoration and management of prairie ecosystems require that the manager understand the physical processes that influence these systems. This section describes the role prairies and grasslands play in controlling water quantity. The rational formula and coefficient of runoff values for different types of materials are important basic theory and concepts regarding the quantity of water.

The characteristics of each watershed determine the quantity and speed of runoff exiting the watershed. Some influencing factors are (Seelye 1954):

- Types of surface; such as soil, rock, asphalt, sod, grass, trees; each type of material has its own coefficient of runoff.
- Types of soil; porosity characteristics; the porosity accounts for the soil's ability to store water.
- Extent and type of vegetation; plant roots take up water and reduce runoff.
- Rates and lengths of slope; refers to the speed and distance runoff has to travel.
- Size, shape, and orientation of watershed; determine the quantity and speed of runoff.
- Number, arrangement, and hydraulic condition of drainage channels; drainage features can aid in controlling water flow; however, if designed poorly can create problems within the watershed.
- Opportunity for ponding of water; this can help hold excess water in the watershed.

Overland flow and runoff. Overland or sheet drainage generally has a slower velocity than water moving in channels, ditches, or streams of the same gradient. Thus, time spent under each condition will be important in determining runoff rates. A number of variables control the rate of runoff over ground surfaces, including: time of overland flow, time of concentration, velocity of water across the surface of the ground, and friction coefficients. Relationships between these variables can be expressed in different formulae and computations, which are used to determine runoff and amount of water flowing across the landscape for planning and design purposes.

Rational formula. The formula often used in the calculation of overland flow and water runoff is the rational formula, because of its simplicity and accuracy. It is quite accurate for small watersheds (<100 acres) and reasonably accurate for watersheds up to 2 square miles (Carpenter 1976). Runoff volumes are computed directly by establishing relationships between rainfall intensities, runoff ratios, watershed acreage, and sometimes slope (Seelye 1954).

The rational formula (Seelye 1954) can be expressed as:

$$Q = ciA \tag{1}$$

where:

Q = runoff in cubic feet per second
c = rainfall/runoff coefficient (roughness factor of the ground surface affecting the rate of runoff)
i = storm intensity (intensity of rainfall in inches per hour for a period equal to the time of concentration (storm event))
A = area of watershed drainage, measured in acres.

Coefficient of runoff. The texture of the surface material affects the mean velocity of water flow traveling across the surface of the ground. The rougher a surface texture is, the slower water will move across the surface. Roughness coefficients are determined for different materials. The value assigned for each type of material indicates the relative protection the material provides from flowing water. Larger values provide greater protection from flowing water.

The roughness coefficient values differ by the types of vegetation and the agricultural treatment of the soil, as indicated in Table 1 (Whisenant 1999). These coefficient values can also change over the course of the growing season and by the amount of growth and residue remaining on the surface. It is interesting to note the two sod types offer a great degree of protection from water flow and are comparable to the value offered by dense shrubs and forest litter. This corresponds to the earlier discussion of the importance of the prairie's underground biomass in increasing the infiltration rate of water and nutrients. By assessing the watershed's coefficient of runoff, a manager can determine areas that function well in controlling sheet flow and areas that can be improved.

Table 1
Coefficient Values for Various Types of Vegetation and Ground Treatments (adapted from Whisenant (1999))

Ground Cover/Treatment	Litter Residue, g/m^2	Coefficient Values	
		Min.	**Max.**
Vegetation			
Shortgrass prairie		0.100	0.200
Dense grass		0.170	0.300
Dense sod		0.325	0.400
Bluegrass (*Poa pratensis*) sod		0.390	0.630
Dense shrubs and forest litter		0.330	0.475
Treatments			
Chisel plow	<60	0.006	0.170
	60-250	0.070	0.340
	250-750	0.190	0.470
Disk /harrow	<60	0.008	0.410
	60-250	0.100	0.250
	250-750	0.140	0.530
Moldboard plow		0.020	0.100

PRAIRIE BEST MANAGEMENT PRACTICES TO IMPROVE WATER QUALITY, QUANTITY, AND YIELD: This section addresses best management practices to maintain quality and stabilize quantity of water within a prairie ecosystem. Site conversion of fallow agricultural fields or open areas to sustaining grassland or prairies is preferable to leaving the site subject to over-land flow and erosion. This section describes the value of a prairie buffer, as well as ways to manage nutrients to maintain ecosystem stability, and control grazing, invasive plants, and brush. For more information on plants, planting, and restoration refer to previous technical notes by Bailey and Martin (2007a, 2007b).

Prairies as Buffers to Waterways. Buffer strips have effectively decreased surface water flows and increased water infiltration in riparian, agricultural, and forested watersheds (Gilliam 1994; Lee et al. 2000). Grassland buffer strips used alone or in conjunction with woody vegetation are effective at removing nitrogen. A 24-ft buffer was shown to reduce 80 percent of the total nitrogen (N) and 62 percent of nitrate (Mayer et al. 2005) and there is a positive correlation between buffer width and the percentage of nitrogen removed. Grasslands may be better at intercepting particulate nitrogen in the sediments of surface runoff by reducing channelized flow (Mayer et al. 2005). A narrow buffer that produces little vegetative biomass may not provide sufficient stocks of organic material for microbial denitrifiers. Mayer et al. concluded that nitrogen removal in the subsurface may be more directly influenced by factors other than buffer width, such as soil type, watershed hydrology, and subsurface biogeochemistry through cumulative effects on microbial denitrification activity.

A three-zone strategy for conservation and management of stream systems and riparian areas is characterized by a zone of mixed grasses and forbs, a middle zone of shrubs and small trees (15-30 ft wide), and a zone of tall trees (15-30 ft wide) adjacent to the waterway. In this three-zone strategy, the grassland will provide filtration of sediments and the shrubs and trees in the other two zones will further intercept sediments in subsoil pathways (Fischer and Fischenich 2000) and help to stabilize the streambank from erosion. Riparian zones in upstream headwaters or backwater regions are important as areas of high nitrogen removal (Mayer et al. 2005). For a 10th order stream, up to 90 percent of the cumulative stream length consists of ephemeral, first and second order streams (National Research Council 2002). The largest proportion of nutrient loads enter the watersheds from the headwaters where the capacity to remove nitrogen is the greatest, while less additional nitrogen processing occurs in the main channels of higher order streams (Mayer et al. 2005). For maximum and long-term effectiveness, buffer integrity should be protected from: 1) soil compaction from vehicles, livestock, and impervious materials that inhibit infiltration, 2) alteration of vegetation (including the removal of litter), and 3) fragmentation caused by disconnecting the stream channel from its floodplain (by building in the floodplain, channelization, and bank erosion).

Nutrient Management to Maintain Ecosystem Stability. The extent of nutrient loss from an ecosystem is one assessment of ecosystem stability (Jackson et al. 1978). Sustainable ecosystems balance nutrient inputs with nutrient losses, but degraded lands must increase nutrient pools by capturing more and/or losing less nutrients (Whisenant 1999). To repair a nutrient cycle, the gap where the nutrient loss is occurring must be closed so the nutrients are maintained in order for the ecosystem to regain full function (Whisenant 1999). Resource retention in a degraded ecosystem is increased with repair strategies such as 1) using vegetation compatible with the nutrient cycling regimes, 2) repairing damaged soil and biotic processes, and 3) adding organic materials to the soil.

Fire is an important component in the management of prairie lands to remove dead thatch and recycle nutrients back into the soil. Prairie plants and animals have adapted to fire within these ecosystems. The Corps has revised its policy on fire management in EP-1130-2-540 (USACE 2005), and does not have a fire management training program in place (USACE 2008). Some Corps resource managers are trained and partner with other entities to conduct prescribed burns on Corps grasslands. However, prescribed burning as a management strategy is beyond the scope of this technical note.

Controlled Grazing. Grazing studies are being done at the Konza Prairie Biological Station in Manhattan, Kansas (Figure 5). The studies involve a herd of approximately 300 buffalo, grazing on 2,500 acres of prairie within a well-fenced area, and research has indicated that grazing benefits the herbaceous and woody components of prairies with proper stocking rates. Stocking rates are critical to preventing removal of prairie grasses, such as Side-oats Grama (*Bouteloua curtipendula*), Big Bluestem (*Andropogon gerardii*), Little Bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and subsequent replacement of lesser quality grasses. If the carrying capacity of the land is not exceeded, grazing generally results in an increase in the root/shoot ratios, particularly on the cooler grasslands (Sims et al. 1978).

Figure 5. Buffalo at the Konza Prairie Research Station (photo courtesy of Mike Watkins).

Buffalos affect the prairie in the same way as cattle, with two important exceptions: buffalo create buffalo wallows, which become important habitat for other prairie wildlife, and cattle tend to be harder on wet and moist sites, compacting the soil particularly around watering areas (Konza Prairie Biological Station 2006). However, the acreage needed for buffalo is significantly greater than cattle; 8 acres or more are needed to maintain one buffalo, depending on the quality of the grassland.

If the stocking rate of cattle exceeds the acreage necessary, damage to prairie ecosystems is a serious concern (Figure 6). Cattle can compact the soil to considerable depths, particularly when the soil is moist. Compacted soil absorbs precipitation poorly, plants get less water, and there is more runoff leading to erosion. Compaction of the soil, removal of vegetation, and cattle trails that form a conduit for serious erosion are all negative consequences that impact a natural prairie system and impair its abilities to store water. When the soil becomes compacted, soil porosity is lost, plant growth rates slow down or cease, and less water is taken up by plants or stored in the soil, increasing soil runoff. Aeration is essential for maximum water absorption because a good oxygen supply is required for the maintenance of the respiration activity and permeability of plant roots (Taylor 1972). The amount of aeration required also depends upon the amount of work that a root must do in expanding against the forces of the soil; as the amount of energy that must be exerted increases, the amount of oxygen necessary for a given growth rate also increases (Taylor 1972).

Figure 6. The size of the herd of cattle grazing is calculated so as not to exceed the carrying capacity of the land, dependent on acreage and type of ecosystem (photo courtesy of P. Bailey).

Control of Invasive species. In the United States, there are 489 native grass species, with an additional 237 introduced grass species. Of these, 137 introduced grass species appear to be established (Flora of North America Editorial Committee 2003). The effects of introduced species extend beyond the displacement of native species and the reduction of diversity, and include the alteration of pools and flows of energy and nutrients in the prairie ecosystem (Christian and Wilson 1999; Wilsey and Polley 2006). Native and introduced grasses have comparable amounts of shallow root biomass and tissue C:N ratios (Wilsey and Polley 2006). However, aboveground productivity and total N were lower, and deep root biomass and root mass fraction (the root-shoot ratio) were greater in native than introduced grasses (Wilsey and Polley 2006). Crested Wheatgrass (*Agropyron cristatum*), an introduced grass planted widely in the northern Great Plains, has 25 percent less root mass than native prairie grass species (Christian and Wilson 1999) and results in less organic

material in the soil. With less root mass and less organic matter, less water will be taken up by the grass and water storage will be reduced. Christian and Wilson (1999) also reported shifts in the nitrogen and carbon cycles. Wilsey and Polley (2006) suggest that grasslands dominated by introduced species in their area have a greater flow of N and C through the aboveground pathway and less N and C flowing to the deeper soil layer. By restoring native species, this trend will be reversed. A greater proportion of roots deeper in the soil will increase drought resistance, micronutrient uptake, and increase C storage in the long run (Wilsey and Polley 2006) and total nitrogen to the soil will create a larger pool of organic matter for mineralization (Christian and Wilson 1999). Greater biomass deeper in the soil is found in water-limited ecosystems (Schenk and Johnson 2002), suggesting native grasses have greater ability to store water by their large underground rooting systems.

Invasive plants can also use great quantities of water and alter the soil chemistry, creating a situation that is favorable for themselves, and inhospitable for native plants. For example, salt cedar (*Tamarix ramosissima*) is an invasive, noxious weed in 13 western states. Water use rates by salt cedar are among the highest of any phreatophyte (plants that use excessive water) evaluated in the Southwest, and can lower the water table up to 4 acre-ft of groundwater annually (U.S. Forest Service (USFS) 2007). Salt Cedar increases soil salinity in the soil by exuding salt through leaf glands that drip onto the soil, creating soil conditions favorable only to itself (USFS 2007). Salt Cedar tolerate 18,000-36,000 ppm salt, whereas native species tolerate a much lower range (1,000-2,000 ppm). Many invasive species are phreatophytes and exhibit a similar tendency to create soil conditions favoring themselves.

Brush Control. Water balance within a prairie will be altered by deep-rooted woody species. Grasslands use water primarily from recent precipitation events, whereas trees obtain water from deeper in the soil profile. The amount of water used by grassland is approximately equal to the amount of rainfall (Scott et. al. 2000) in summer months, but trees such as Honey Mesquite (*Prosopis velutina*) were found to take up more water than the rainfall event supplied. Trees and shrubby species generally transpire more water than grass and herbaceous cover. In a study investigating the removal of Ash Juniper (*Juniperus ashei*) from a Texas grassland (Dugas et al. 1998), evapotranspiration was reduced in the treated area, and more water was found to be stored in the soil and grass component on the site. In a second study, Wu et al. (2001) reported decreased water yield due to increased evapotranspiration loss associated with compositional changes in woody vegetation from oak to juniper. Brush management was suggested as a means to increase water yield within a prairie or grassland.

Mesquite is a southwestern shrub/small tree that grows rapidly and will become the dominate vegetation within the landscape. Once mesquite is established, only a few plant species will grow under its canopy, further degrading the ecosystem by reducing biodiversity. This is a downward cycle of degradation that would take significant time to repair, until fire is brought back into the system. Prairie ecosystems are fire-dependent systems. If fire is removed from the prairie ecosystem, shrubs start to invade the grasslands. This causes the distribution of nutrient and water resources to become patchy and concentrated under the shrubs, and the surrounding areas become drier. This process has been described as an autogenic process that promotes the persistence of shrubs (Schlesinger et al. 1990) and this conversion degrades the overall stability of the environment. For

example, if a grassland in the arid Southwest is disturbed, resources become distributed unevenly, creating conditions favorable for mesquite (*Prosopis* sp.) invasion.

CONCLUSIONS: Prairies are important in watershed protection because they fulfill multiple functions on a landscape scale. Prairies serve as a buffer to impede sediment and non-point source pollution from entering waterways; they provide erosion control, nutrient cycling, and water purification, while providing wildlife habitat. Many Corps projects contain substantial prairie and grassland acreage, which have a significant impact on water quality, quantity, and conservation efforts in watersheds across the nation. Best management practices for water conservation include nutrient management to maintain ecosystem stability, management of prairies to act as buffers to waterways, control of stocking rate of cattle on grasslands to prevent overgrazing, and prevention of impacts by invasive species. By understanding the natural processes by which prairie lands improve water quality and control water quantity, one will realize how valuable the Corps' prairie lands are for the sustainable management of Corps lakes and waterways. Managing prairie lands offers a sustainable watershed–wide approach, which is not only important to the Corps, but also to the nation by providing watershed protection on a landscape scale.

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SUMMARY: This technical note describes how prairies function to maintain water quality by filtration, sediment trapping, and nutrient cycling. The section on water quantity describes how prairie lands aid in the control of erosion and runoff. The Rational Formula and coefficient of runoff values are explained. The last section on best management practices for water conservation includes information on nutrient management to maintain ecosystem stability, how prairies act as buffers to waterways, consideration of carrying capacity of cattle and other herd animals on grasslands to prevent overgrazing, soil compaction and erosion, and lastly the control of invasive species and brush to keep from degrading prairie lands.

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> Bailey, P. 2009. *Prairies and water management on Corps lands.* EMRRP Technical Notes Collection (ERDC TN-EMRRP-ER-11). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

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ADDITIONAL INFORMATION WEBSITES:

North American Prairie Conference. 2008. *www.winona.edu/NAPC/*

The Society for Ecological Restoration International, *www.ser.org* / 23 June 2006.